PySALT: The SALT Science Pipeline

Steven M. Crawford*[a,b], Martin Still[c], Pim Schellart[a,d], Luis Balona[a], David A. H. Buckley[a,b], Garith Dugmore[a], Amanda A. S. Gulbis[a,b], Alexei Kniazev[a,b], Marissa Kotze[a,e], Nicola Loaring[a,b], Kenneth H. Nordsieck[f], Timothy E. Pickering[a,b], Stephen Potter[a], Encarni Romero Colmenero[a,b], Petri Vaisanen[a,b], Theodore Williams[g], Ewald Zietsman[a,h]

[a]South African Astronomical Observatory, PO Box 9, Observatory, Cape Town, RSA 7935; [b]Southern African Large Telescope, PO Box 9, Observatory, Cape Town, RSA 7935; [c]NASA Ames Research Center, Moffett Field, USA 95014; [d]Radboud University, Nijmegen Netherlands; [e]University of Cape Town, Cape Town, RSA; [f]University of Wisconsin, Madison, Wisconsin, USA; [g]Rutgers University, Piscataway, NJ, USA; [h]University of South Africa, RSA

Abstract

PySALT is the python/PyRAF-based data reduction and analysis pipeline for the Southern African Large Telescope (SALT), a modern 10m class telescope with a large user community consisting of 13 partner institutions. The two first generation instruments on SALT are SALTICAM, a wide-field imager, and the Robert Stobie Spectrograph (RSS). Along with traditional imaging and spectroscopy modes, these instruments provide a wide range of observing modes, including Fabry-Perot imaging, polarimetric observations, and high-speed observations. Due to the large user community, resources available, and unique observational modes of SALT, the development of reduction and analysis software is key to maximizing the scientific return of the telescope. PySALT is developed in the Python/PyRAF environment and takes advantage of a large library of open-source astronomical software. The goals in the development of PySALT are: (1) Provide science quality reductions for the major operational modes of SALT, (2) Create analysis tools for the unique modes of SALT, and (3) Create a framework for the archiving and distribution of SALT data. The data reduction software currently provides support for the reduction and analysis of regular imaging, high-speed imaging, and long slit spectroscopy with planned support for multi-object spectroscopy, high-speed spectroscopy, Fabry-Perot imaging, and polarimetric data sets. We will describe the development and current status of PySALT and highlight its benefits through early scientific results from SALT.

Keywords: Pipelines, SALT, PySALT

1. Introduction

As the typical observations move further away from an astronomer looking through an eyepiece, data pipelines have increased in their importance to the performance of a telescope. With the growing complexity of observations, it is invaluable to provide the tools necessary for data reduction and analysis in terms of producing timely scientific reductions. The development of pipelines reduces redundant work and allows researchers to focus on maximizing their time on understanding scientific observations. Furthermore, archives of science quality data are generating a greater fraction of scientific publications, and making these archives publicly available maximizes a facility's scientific return.[1]

For a queue mode operated telescope like the Southern African Large Telescope (SALT), it is imperative to have a pipeline in place for data handling and distribution due to the removed nature of the principle investigators. One of the key science goals of SALT is the exploration of time domain astrophysics, rapid delivery of scientific quality data is critical to maximizing its productivity. In addition, the instrument suite available to scientists on SALT has a range of instruments that explore domains (mainly time) that are usually not explored on 10m class telescopes, and it is important to have tools to handle these unique data sets. These considerations led to the development of PySALT.

In this contribution, we present PySALT, the software and data pipeline for the SALT telescope. In the following section, we describe SALT and the instruments associated with it. Then, we present the design requirements, goals, and general philosophy in the pipeline and PySALT development. In Section 3, we describe the basics of the pipeline software and how it handles SALT observations. Next we describe the basic data reduction tools that have been developed to provide

* crawford@saao.ac.za phone +27 21 460 9359, fax +27 21 447 3639, http://stevecrawford.saao.ac.za/

science quality data reductions to SALT proposers. In Section 5, we describe the additional analysis tools that have been developed to reduce data for SALT observations. Finally, we provide some scientific highlights that show the usefulness of the pipeline software.

Additional information about the PySALT software package are available at the SALT website[2] along with the most recent versions of the software.

1.1 Southern African Large Telescope

SALT is a 10m class telescope built at the Sutherland observing station in South Africa by a consortium of 13 partners[†]. The design of SALT is based on the Hobby-Ebberly telescope (HET) and works in a similar manner as the Arecibo Radio Telescope. The spherical primary mirror, composed of 91 1.2m hexagonal segments, is fixed at an angle of 37^{o} with respect to the zenith, and science observations are performed with the 'tracker' that follows targets across the sky. Due to the fixed nature of the primary, the telescope can only observe objects that are between $-75^{\circ} < \delta < +10^{\circ}$ in declination, and the length of the track (how long a target can be continuously observed) depends on the declination. Details about the design, commissioning, and status of the telescope can be found in previous proceedings[3] (see references therein) and the first scientific results were published in 2006[4]

The two first light instruments on SALT are SALTICAM and the Robert Stobie Spectrograph (RSS). SALTICAM[5] is an imaging and acquisition camera with the following modes of operation: normal imaging, frame-transfer imaging, high-speed imaging, and drift scanning. SALTICAM is composed of two 2048x4096 CCDs to provide a full field of view of 8' diameter at a sampling of 0.14"/pixel. In slot mode, SALTICAM can provide sampling at a rate of ~20 Hz over an 8'x120" slit. Over 23 filters are available for SALTICAM including standard filters and speciality narrow band filters.

RSS[6,7 8] is a prime focus, multi-mode spectrograph to support a wide range of scientific investigation. RSS provides imaging, long-slit spectroscopy, multi-object spectroscopy, high-speed spectroscopy, Fabry-Perot imaging[9], and polarimetry along with the combination of any of those modes. The detector consists of three 2048x4096 CCDs with 15 micron pixels and a plate scale of 224 micron/arcsec and imaging can be done over an 8' field of view. A large number of ~100 Å narrow bands, used for order blocking with the Fabry-Perot etalons, are also available for imaging.
A suite of VPH gratings are available and allow for spectral resolutions ranging from R~500 to 5500 with 1" slit widths. The Fabry-Perot etalons allow resolutions between R~500-12500. Multiple polarization modes are possible including linear, circular, and 'All-Stokes.' Many of the modes can be used in combination and at high speed.

In addition to the first light instruments, the Berkley Visible Image Tube (BVIT) was installed on the telescope during early 2009. This auxiliary port instrument is a micro-channel plate, photon-counting detector system designed for microsecond optical photometric imaging.[10] Unlike conventional CCD devices, the S-20 photocathode has no read noise and is capable of recording photon events in very short time intervals. The instrument can handle data rates up to ~1.1 MHz, and events are time-tagged to 25 nsec. BVIT has a 1.9' diameter field of view and contains user-selectable UBVR and neutral density filters.

SALT is operated entirely in queue mode, which maximizes the efficiency of the telescope due to the fixed nature of the SALT primary. As such, observations on SALT are made by the SALT Astronomers (SAs) for the principle investigators (PIs). Under normal operations, PIs from partner institutions would submit a Phase I proposal for observing time. Once that is accepted by their local telescope allocation committees, the PI would submit a Phase II proposal with further details of the observation. During the proposal phase, information about the observations is inserted in the science database (Sdb). The Sdb is a MySQL database that includes the proposal information, the telescope configurations, and records of the observations. SALT observations are scheduled in blocks, which are the minimum required amount of time that needs to be scheduled for an observation. A block could be as little as a single image of a single target, or multiple observations including different targets, instruments, and configurations. Once the observation information is in the Sdb, the information is then available at the telescope and included in the queue scheduler. Once ready, the SA can select those observations and obtain data for that proposal. Throughout the night, the data are transfered to Cape Town where they will be processed by the pipeline and then distributed to the PIs, typically by the next day.

[†]The SALT consortium consists of including the National Research Foundation of South Africa, Nicholas Copernicus Astronomical Center of the Polish Academy of Sciences, Hobby Eberly Telescope Founding Institutions, Rutgers University, Georg-August-Universitat Gottingen, University of Wisconsin-Madison, Carnegie Mellon University, University of Canterbury, United Kingdom SALT Consortium, University of North Carolina-Chapel Hill, Dartmouth College, American Museum of Natural History and the Inter-University Centre for Astronomy and Astrophysics, India.

SALT had first light in November 2005. After the first year of observations, two major problems were discovered. The first involved the UV throughput for RSS. Due to a reaction involving the lens fluid, the UV throughput was dramatically reduced. In November 2006, the instrument was removed from the telescope for further investigations. With a new lens
coupling fluid, the instrument was returned to South Africa in 2009 and no further problems have been observed with the UV throughput. Since it was removed, SALT had been in limited operations with SALTICAM being the primary instrument. The second major issue was that SALT was suffering from an image quality issue[11]. The main source of the degradation in the image quality was the Spherical Aberration Corrector (SAC). This was removed in April 2009 and is expected to return to the telescope in late 2010 after a redesign of its interface with the telescope along with realignment. Since it was removed, the telescope has not been in operation.

2. Goals and Philosophy of SALT Science Software Development

The primary goal for the development of SALT science software is to increase the scientific productivity of the telescope. By providing fast access to high quality data, we can minimize the effort required to publish scientific results . Furthermore, by having a central resource provide the tools necessary for data reduction, the amount of redundant work done by the diverse partnership is minimized. To achieve this goal, we have identified three critical areas of software development:

I. Provide science quality reductions for the major operational modes of SALT.
II. Create analysis tools for the unique modes of SALT.
III. Create a framework for the archiving and rapid distribution of SALT data.

Obviously providing science quality data reductions to the investigators will have an immediate return by minimizing the amount of work required for the principle investigators to publish their results. As it is a large consortium with many members having similar data reduction needs, the existence of a common framework for data reduction minimizes the amount of redundant work that needs to be done.

SALT has many unique modes of operation that are rarely found on 10m class telescopes. The data sets produced by these modes typically have multiple dimensions and are best represented by data cubes. Tools for analysis and visualization allow access and analyze the data. In addition, these tools provide a way for new users to access these modes with a minimum amount of overhead, allowing for new scientific exploration.

Finally, it will be important to provide a framework for the data archiving and distribution of the data. The remote nature of the telescope requires automated data handling to be in place to provide the necessary science and calibration images to the researchers along with additional information about the observations. Rapid access to the data will allow researchers to supply feedback to the SAs, as well as to begin their data analysis. Measuring and tracking the data quality will provide a method for assessing the performance of the telescope. Archiving the data, including careful records of the observation's meta-data, will allow future access of the data through Virtual Observatory tools to allow for more scientific research.

2.2 Python/PyRAF as a Development Environment

Our choice of Python[12] and PyRAF[13] as a development environment for the SALT science software was due to several reasons. First, Python is a well supported high-level language that has been rapidly gaining support in the astronomical community. As a scripting language, Python provides an easy environment for information manipulation, interaction with databases, and different communication protocols. The numpy[14], pyfits[15], and scipy[16] libraries provide access to very fast array handling and manipulation software, and matplotlib[17] is a sophisticated software library for data visualization. The ease in wrapping other software with Python has provided low-level access to a wide range of astronomical software such as ds9[18], Sextractor[19], and IRAF[20].

Further, PyRAF is the Python wrapper for IRAF developed by Space Telescope Science Institute. The software provides access to existing IRAF tasks that greatly enhances the ability of Python for reduction of astronomy data. However, it also is an enhancement of the IRAF operating environment, so that Python libraries can be imported into a working environment that behaves in a very similar manner to the IRAF environment. PyRAF tasks still have parameter and help files, but can interface both with IRAF and Python tools. The resulting combination of the extensive library of astronomy data reduction tools for IRAF along with the flexibility of Python is a powerful tool for data handling and analysis.

An important aspect of this development is the open-source nature of these tools. In the South African and many other African research communities, software with restrictive or expensive licenses are prohibited due to the lack of resources. Along with contributing to the cost-effective nature of SALT, open source software is far more accessible to these communities. As such, we have also adopted an open source license for all SALT software and avoided requiring any closed source or cost prohibitive software.

2.3 Overview of the PySALT package

The PySALT package is organized into several sub-packages with each packaged meant to implement one of the key goals for PySALT for a specific mode. Figure 1 highlights the different packages which are currently part of the development package of PySALT. PIPETOOLS is software primarily involved with the data handling and archiving. The SALTRED, SALTSPEC, and SALTFP are packages that reduce different modes of SALT data. Finally the SLOTTOOLS and BVITTOOLS packages produce scientific analysis for high speed observations. The laste major release of the software was on 6 March 2009. The next release, which will include the additions of the SALTSPEC and BVITTOOLS package along with major upgrades to the architecture of the software, is expected to be released in mid-2010. After SALT becomes operational we plan to maintain a six month release cycle.

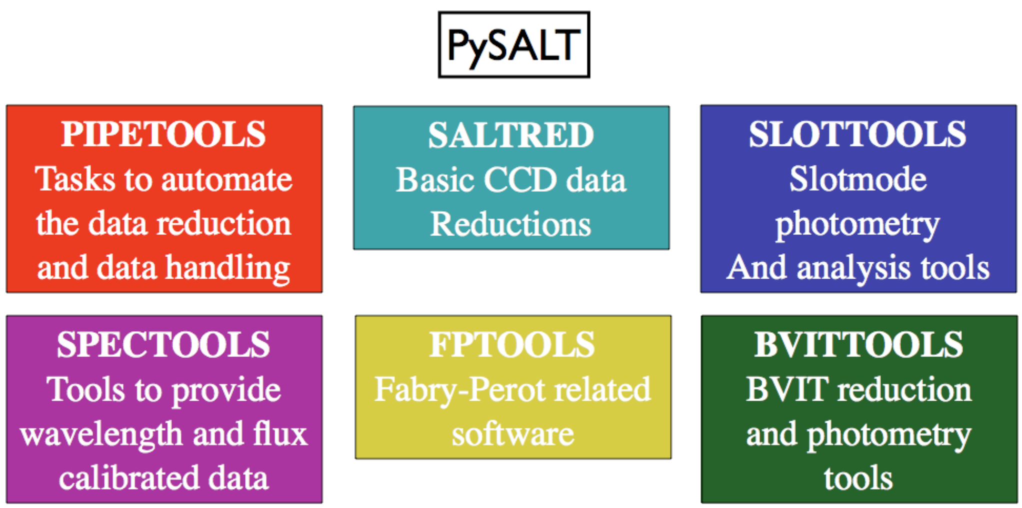

Figure 1. Packages in the PySALT software

3. Data Pipeline

The telescope is operated in queue mode due to observing constraints, and all observations are done by the SAs. Combined with the geographical spread of the partner institutions and the relative isolation of South Africa, principle investigators will only be remotely involved with their observations. Because of the limited observing time available for a given object during a night, the full observations of a program may only be completed over a period of weeks or months for any target. Likewise, target of opportunity observations and temporal resolved studies are two of the key science drivers of SALT. Due to these reasons, a critical requirement for the development of the science software is the ability to automatically process and distribute the data. In addition, maintaining the data archive of the observations is a important task for any modern facility. The development of the data pipeline handles these tasks along with providing rapid feedback to the investigators.

In its current form, the SALT data pipeline handles a number of different tasks that start after the data have been transfered from Sutherland to Cape Town. The initial step is to verify that all of the data has been transfered from the telescope. Next, the data go through some initial pre-processing. The primary function during this task is to convert all the data to FITS format. Due to the nature of high speed data, the information is stored in binary format and it is only in this step where FITS files are created. In addition, any errors in the headers will also be fixed during this process. The next step is to create observing logs for each of the nights observations. This is followed by performing basic data reductions on each of the fields. More details of this are below. Once the reductions are complete, data belonging to individual proposal are identified, documentation is created, and then the pipeline pauses. At this point, a SALT astronomer on Cape Town duty will check the performance of the pipeline and re-run it if there has been any problems. They will also perform some random spot-checks of the data.

If there were no problems, they will re-initiate the pipeline. From there, the pipeline will move data for individual investigators to their staging areas on an FTP server. An email notification indicating that data are ready will be sent to the investigator. Finally the data are archived and details of the observations are stored in the Sdb.

In addition to this mode, the pipeline is also run in 'fast' mode. In this mode, the raw data files are made available to the PI as soon as they are available in Cape Town. This is critical for time sensitive observations and allows for rapid feedback on the observations. A successful example of this mode is given below.

Compared to some large telescopes, the data rates at SALT are relatively modest. For the period between November 2005 (first light) to April 2009 (removal of the SAC), we plot the amount of data taken during each night in Figure 2. Even though data rates are modest, the limited amount of band width in South Africa has been the bottle neck in the data processing.

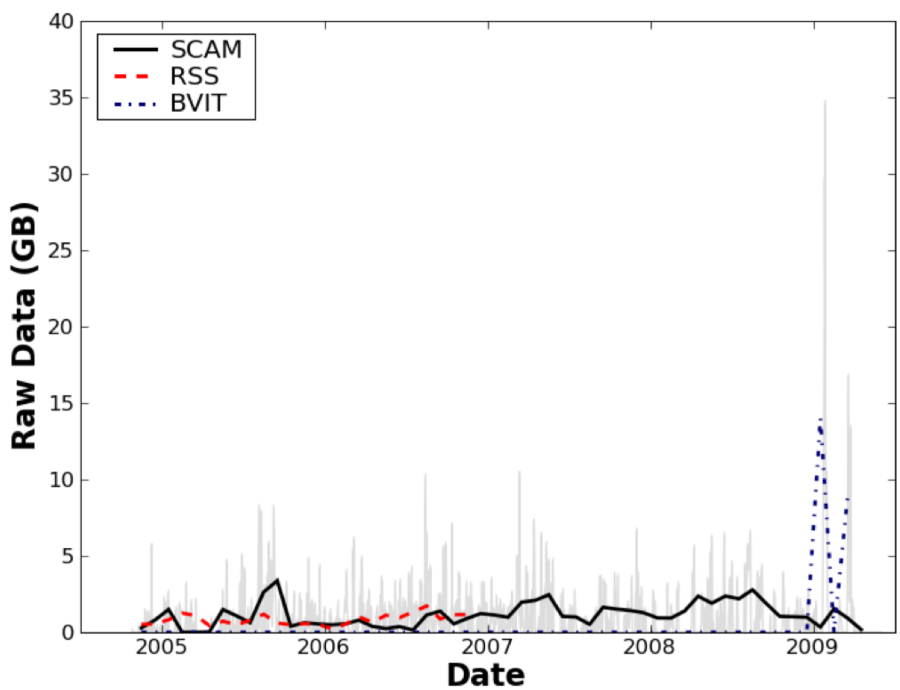

Figure 2. The amount of raw data per night produced by SALT since first light. The black solid line represents the monthly per night average (excludes closed nights) amount of raw data created by SALTICAM observations (including calibration data). The red, dashed line represents RSS, which was removed from the SALT in Nov 2006. The blue, dot-dashed is for BVIT. The grey lines represent the total data observing each night by SALT.

In Cape Town, the pipeline runs on a Quad Core Intel Xeon 3.16 GHz processor with 8 GB of memory. The server has 240 GB hard disk memory set up in a RAID10 configuration. The advantage of this set up is providing fast data I/O, which for SALT data reductions is typically the limiting factor to its performance. For a typical night with 2.5 GB amount of data, the pipeline takes approximately 30 minutes to run.

Future development of the pipeline includes providing greater information and resources to both the SA and the PI. This includes monitoring the data quality of the observations and tracking any changes occurring to the system. For the PI, we hope to include more information about the observations included environmental, seeing, and throughput measurements. As bandwidth in South Africa continues to improve, we look forward to providing real time access to the data for time sensitive proposals.

Tasks in the pipeline software are not available in the releases of PySALT but are available as part of the PySALT development package.

4. Data Reduction Software

4.1 Basic Data Reduction Software

Basic CCD data reductions are implemented as part of the SALTRED package in PySALT. The full list of tasks that will be implemented as part of the SALTRED package are listed in Table 1. For imaging, it will provide tools for image reduction including gain and cross-talk correction, bias subtraction, flat-fielding and fringe correction, distortion correction, and astrometric solutions. For other modes, it will provide the same reductions through distortion correction, at which point further reductions will be handled by packages specific to that mode. Further descriptions of each task are provided on the SALT website.

Table 1. Tasks that are included in the SALTRED package

Name	Description
saltprepare	Prepare FITS files for SALTRED reduction
saltgain	Gain correct images
saltxtalk	Correct images for amplifier cross talk
saltbias	Create master bias frame and/or de-bias images
saltflat	Flatfield correct the images
saltfringe	Fringe correct the images
saltcrclean	Clean cosmic rays
saltmosaic	Mosaic CCD amplifier images and apply distortion correction
saltastrom	Determine astrometric solution
salttimes	Convert to different time systems
saltslot	Reduce slotmode images
saltclean	Reduce SALT data

All of the tasks have been implemented with both speed and flexibility in mind. When available, the first implementation of each task utilized an IRAF task (or other existing software) and took advantage of existing tools for these corrections. To increase the speed and performance of the tasks, we have replaced the IRAF task with a Python implementation for certain modes of operation. In the end, we have leveraged the extensive history of selected IRAF tools to provide the user with reliable existing tools while enhancing the performance with new, more powerful code.

In the current pipeline, reduction of SALT observations are handled by *saltclean*. The task identifies the images, needed calibration data, and then applied each of the reduction steps. Currently, we only implement gain, crosstalk, overscan, and distortion corrections. Overscan subtractions are sufficient to correct for the bias levels for SALT data. Calibration frames have not been obtained for flat-fielding or fringe corrections due to scattered light issues that will only be resolved once repairs on the SAC are complete. Along with cosmic ray cleaning and astrometric solutions, we expected all of these steps to be performed once we begin full operations.

Slotmode reductions are handled by *saltslot*. To further enhance the performance of the data reductions, the files are only opened once and all of the reductions tasks are performed sequentially on the file. Only three corrections are applied currently as part of the pipeline process, which include gain, cross-talk, and overscan subtraction.

Future development of the code is focused on increasing performance and usability of the functions. An important addition will be to implement variance and bad pixel frames. Furthermore, we hope to replace some of the IRAF tasks with faster algorithms for data reduction to further improve the performance of the pipeline.

4.2 Advanced Spectroscopic Reductions

Advanced spectroscopic reductions are part of the SALTSPEC package and include all the steps necessary to produce wavelength calibrated 1-D spectra from long slit spectra. The tasks that are part of this package are listed in Table 2. The package was designed to provide automated reduction of SALT images. Design of the software was based on reduction of observations[21,22,23,24] obtained prior to the removal of RSS. The automated procedures are meant to produce high quality scientific reductions and are built for general use. They should be applicable to different observing modes and targets. However, different reductions tools may provide better results, but these should be applicable to most tasks.

Table 2. Tasks that are in the SALTSPEC package

Name	Description
specprepare	Prepare FITS files for SALTSPEC reduction
specidentify	Gain correct images
specrectify	Correct images for amplifier cross talk
specsky	Sky subtract spectra data
specextract	Extract 1D spectra for SALT images
specreduce	Fully reduce SALT spectroscopic data

The main task of the package is *specidentify,* which determines the wavelength solution for the arc lamps. Although the task includes an interactive mode, it is primarily designed to work without any human intervention and calculate the wavelength solution over the full frame. The *specidentify* task is built around the PySpectrograph package that produces a model of the spectrograph. Because the configuration of RSS is known very well, the model of the spectrograph provides a solution that is within a few percent of the actual solution. The model can be updated with calibration data to improve its performance further, but for many purposes, this model provides a sufficient solution for the images. However, *specidentify* only uses this model for a first guess for the wavelength solution. The actual wavelength solution is determined by cross-correlating the observed arc line observations with an artificial spectrum. The artificial spectrum is created from the line list that includes both wavelength information and line ratios. Having extensive and well maintained line lists will be critical for delivering automated data reductions. By having a very close approximation to the wavelength solution, we can produce an artificial spectrum with similar resolution as the observations, which minimizes the problem of line blending.

The PySpectrograph model uses information about the system to model the spectrograph and is built upon the spectrograph equations.[25] The model is built upon the grating equation:

$$n\lambda = \sigma \cos(\gamma)\,(\sin(\alpha) \pm \sin(\beta)) \qquad (1)$$

In this equation, λ is the wavelength, n is the order number, σ is the distance between the lines on a grating. For RSS, α is the grating angle, β is the grating angle minus the camera angle, and γ is the angle in the spatial direction. Combing the information about the focal length and size of the camera, collimator, and telescope along with the properties of the gratings, slit, and detectors, a very accurate prediction can be made for the properties of the resultant spectra.

An example of this process is given in Figure 3. In the top frame, we provide an example of the spectra created using the PySpectrograph model for RSS. In the next figure, we provide an example of an Xe arc lamp image from SALT. Finally, we show the same spectra after wavelength calibration. The wavelength solution was generated automatically. In Figure 3, we plot the centroid for different arc lines as a function of y-position for different lamps and spectrograph configurations.

Future development of the SALT spectroscopy software includes providing support for multi-object and high speed modes. An important part of the spectrograph package will be integrating it into the pipeline to automatically produce wavelength calibrated data.

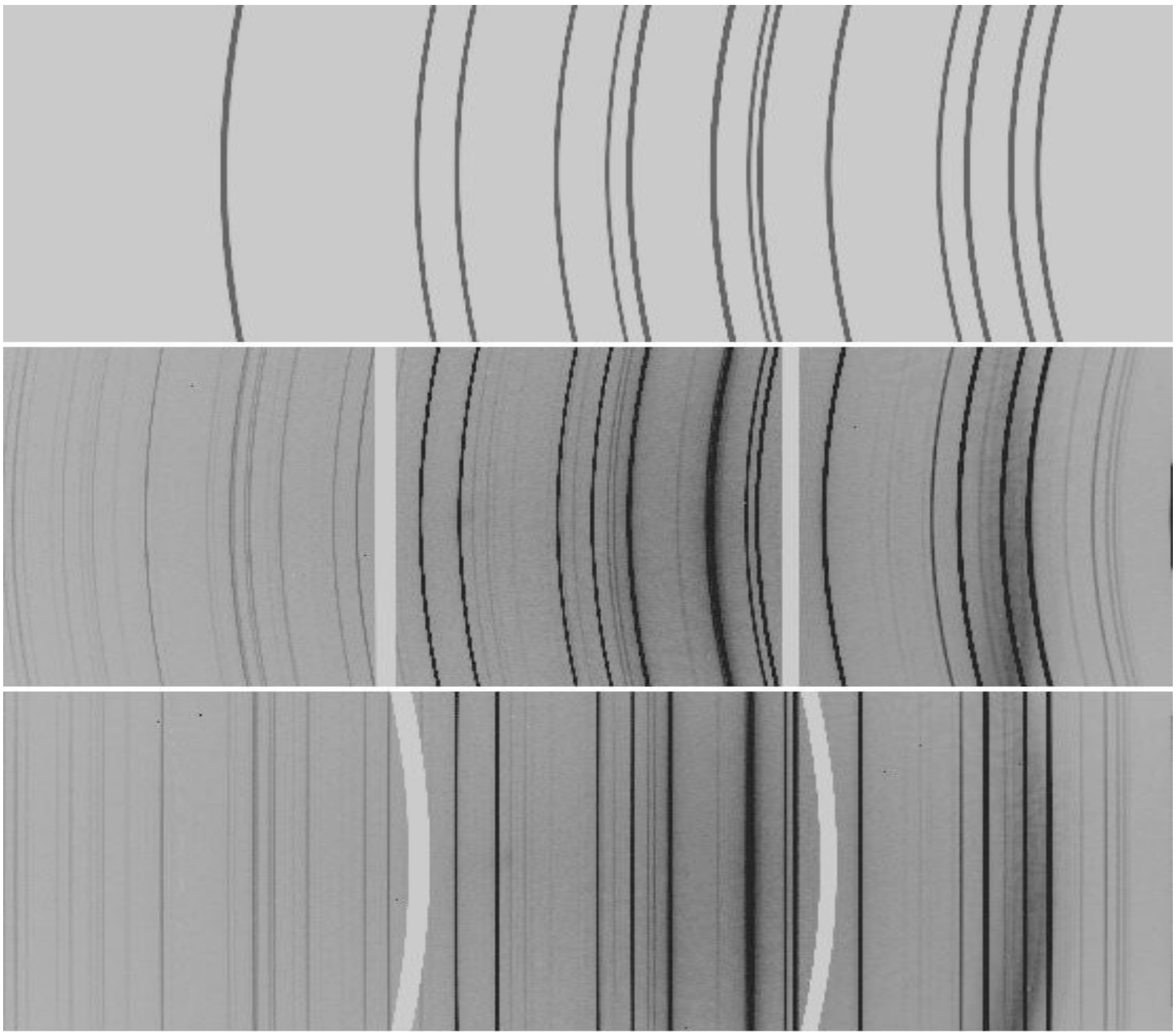

Figure 2. Example of an RSS long slit observation of an Xe arc lamp using the PG3000 grating. The top image is an artificial image created from the Xe line list, the middle image is an RSS observation of the lamp, and the bottom image is the image after applying the automatically-determined wavelength solution.

4.3 Support for other SALT modes

In addition to the two main modes mentioned here, advanced data reduction routines are in development for the other modes of SALT observations. For RSS, Fabry-Perot and polarimetric reduction packages are currently in development. The Fabry-Perot package is built around existing fortran data reduction software that will provide a comprehensive suite of tasks to aid the user in standard FP data reduction and analysis. The polarimetric reductions tasks will be additions to the existing tools in the PySALT package. In addition to SALTICAM and RSS, we have also provided reduction software for BVIT as part of the PySALT package.

In the PySALT package, we also plan to support the two next generation instruments on RSS. The High Resolution Spectrograph[26] (HRS) is planned to come online in mid-2011 and produce spectra with resolutions up to R~100,000. In 2010 the near-infrared (NIR) upgrade to RSS will be completed[27]. The NIR arm for the RSS will provide simultaneous optical-NIR wavelength coverage and similar modes of functionality that are available on RSS now.

5. Data Analysis Software

Support for unique modes is as important an aspect for producing rapid scientific results as for having scientific quality data reductions. SALT has a number of modes which are relatively rare for a 10m class telescope. Because of the differences in data format, data rates, and observational technique; it is important to develop tools for analysis for modes such as high-speed observations. In reality, these tools minimize redundant work by members of the consortium; remove some of the obstacles in accessing interesting, but obscure modes; and provided a shorter path to publication. So far, we have provided tools for the analysis of slotmode data, but we also hope to support modes such as high-speed spectroscopy, Fabry-Perot imaging, and polarimetry.

Slotmode data anlysis is provided by the SLOTTOOLS package. The tasks in the package are outlined in Table 3. The task perform all of the necessary steps to create light curves for a source in reduced slotmode imaging data.

Table 3. Tasks that are in the SLOTTOOLS package

Name	Description
slotpreview	Prepare files for slotphot
slotphot	Photometry extraction for slot mode observations
slotview	Analysis and display tool for slot mode data
slotmerge	Merge multiple amplifiers into one image
slotutcfix	Correct UTC times in slotmode data headers

The primary task of the package is *slotphot* that creates the lightcurve from SALT slotmode data. Once the user has identified the target and comparison star, the program will identify all of the relevant data extensions (slotmode data is saved in Multi-Extension Fits (MEF) format and a single file can have many exposures), subtract global and local background from the sources, perform photometry, and create the light curve. The users has multiple different options for how the background subtraction and the photometry are performed. For photometry, the user can select from aperture, curve of growth, or optimal. In optimal mode, the light distribution for the comparison star is used as a model point spread function for the target star and provides highly accurate relative photometry.

Once complete, the user can view the light curve using *slotview*. An example of *slotview* is shown in Figure 3. The user can display the light curves of the individual sources along with the data frame from which the photometry measurement was made. From here the user can examine the photometry, repeat it if necessary, or delete sources. It provides a useful tool for examining and improving the measurements.

More details of the SLOTTOOLS package are provided on the SALT website which include a manual for slotmode data analysis and a detailed explanation of the slotmode UTC bug. Due to a glitch in the SALTICAM instrument software and computer, the UTC timing values recorded in the image headers showed unusual behavior. Although the instrument was reading out the data at regular intervals, the timing did not record this. A post-processing software solution has been provided as part of the SLOTTOOLS package for any observations taken with SALTICAM instrument software prior to version 4.78. The problem has been fixed in the most recent version of the SALTICAM software.

In additional to the SLOTTOOLS package, the BVITTOOLS package provides the same functionality for BVIT. In addition to some tools to put the BVIT data into more familiar formats, the package has the same three tasks to preview the data and prepare it for photometry, perform photometry, and analyze the data.

In the future, we hope to provide software tools for modes beyond slotmode and SALTICAM. For example, some of the SLOTTOOLS software were adopted to be used for BVIT, which is also a high speed imager. Although many of the more traditional modes have a range of scientific tools available for their analysis, tools for the analysis of high speed modes are still in their relative infancy. The release of the SLOTTOOLS package provided a high quality and easy-to-use scientific analysis package that has resulted in several papers which are highlighted below.

6. Early Scientific Highlights

Despite limited operations, SALT observations still have resulted in a number of publications. In this section, we highlight some of the scientific results that have used the PySALT science software and how that software has aided the publication of the work.

6.1 Observations of Near Earth Asteroids

One of the early successes of fast data distribution is the work by Kwiatkowski et al.[28,29] to study near-Earth asteroids. In this work, they measured the light curve of 14 asteroids and determined synodic periods for the objects ranging between 77 s to 44 minutes. The measured period places constraints on different models for the interior composition of the asteroids. The fast response time and queue based nature of the observations were optimal for the program. As the data were typically available the day after the observations, the PI could update the SA with new, more accurate coordinates for the next night. Due to the rate of non-sidereal movement, the availability of new coordinates greatly improved the scheduling of targets for higher quality observations.

6.2 High Speed Photometry of Stellar Objects

The availability of a high speed camera on a 10m class telescope, even in the limited operations mode of SALT, still provides a unique resource for scientific investigation. Further examples are provided in the proceedings for this conference[30], but here we highlight some of the most recent work. For example, Revnivstev et al.[31] used SALT slotmode photometry as part of a larger study of intermediate polars to determine the properties of the accreting disc of cataclysmic variables. Zietsman et al.[32] observed the eclipsing polar HY Eri with SALT to determine the geometry of the system. They used the automated reductions along with the other tools provided as part of the PySALT to produce light curves of the source. An example of these light curves are provided in Figure 4. A number of features are evident in the light curve starting with the out of eclipse stage (0), the ingress (1) and eclipsing of the accretion stream (2), full eclipse (3), the re-appearance of the accretion shock (4), and gradual rise as the object moves out of eclipse (5). From modeling the light curve, the white dwarf appears to be fed by two highly non-ballistic accretion streams that are magnetically dominated.

4. Summary

We have presented PySALT, the SALT science software package. PySALT satisfies three different needs of the observatory: 1) Pipeline software to handle data distribution and archiving, 2) Reduction software for a range of instrumentation, and 3) Data analysis software. At this time, the data pipeline has provided rapid access to the SALT observations along with reliable reductions. Software tools exist, or are in development, for the full reductions of normal imaging, high speed observations, spectroscopy observations, Fabry-Perot data, and polarimetric observations. Tools for the analysis of slotmode data have already paid dividends in terms of scientific publications despite the limited nature of observations at SALT.

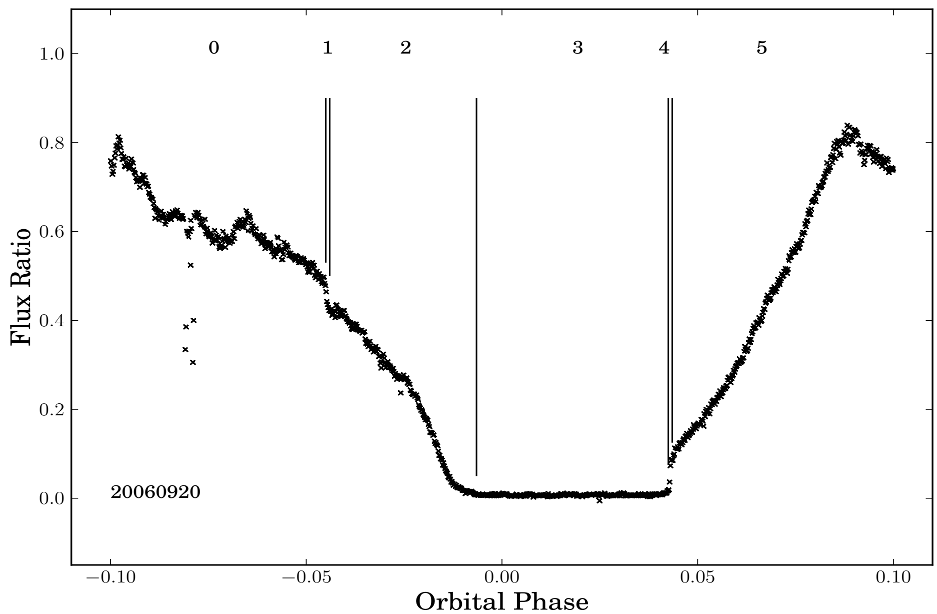

Figure 4. Light Curve centered on mid-eclipse for HY Eri as measured with SALTICAM on 20 Sept 2006. Different stages of the eclipse are identified in the light curve and are described in the text.

The SALT partnership is a diverse collection of countries, institutes, cultures, and scientist. Many in the consortium are faced with similar problems in terms of basic data reduction and analysis although they may have very different scientific aspirations. By providing tools for these shared problems and solving issues collaboratively, we can minimize the amount of redundant work while optimizing the performance of the facility. Development of PySALT has initially been driven by work at SAAO, but its performance has been greatly aided by contributions and feedback from across the consortium. Due to the nature of the collaboration, the full success of the software and the telescope will depend on the future contributions and participation of the partnership.

Acknowledgements: Many people have contributed to the PySALT package and development, but we would especially like to thank the support provided by Phil Charles along with the other members of the SALT team. Much of this work could not be completed with out the feedback, participation, and enthusiasm of members of the SALT consortium. Funding and support for this work were provided by the National Research Foundation of South Africa and the Southern African Large Telescope.

All of the observations reported in this paper were obtained with the Southern African Large Telescope (SALT), a consortium consisting of the National Research Foundation of South Africa, Nicholas Copernicus Astronomical Center of the Polish Academy of Sciences, Hobby Eberly Telescope Founding Institutions, Rutgers University, Georg-August-Universitat Gottingen, University of Wisconsin-Madison, Carnegie Mellon University, University of Canterbury, United Kingdom SALT Consortium, University of North Carolina-Chapel Hill, Dartmouth College, American Museum of Natural History and the Inter-University Centre for Astronomy and Astrophysics, India.

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